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But above all, it has been discoveries resulting from the opening up of new paths of investigation which have impressed both the scientific and the popular mind with the importance of medical science. In the last three decades medicine has advanced to a position where it stands as never before in the very closest relations to the highest interests of human society. When you consider the vast accumulations of population in cities, the great industrial activities of modern times, the efforts to colonize and to reclaim for civilization tropical countries and waste lands, such a stupendous undertaking as the digging of the Panama Canal, all dependent in a very direct manner upon our power to control the spread of epidemic and endemic diseases, and that this power has come from the discovery of parasitic microorganisms and the study of their properties and of the manner of propagation of agents of infection, it must be clear to you that medicine, especially preventive medicine, is most intimately related to the progress of civilization and the advancement of human society. So the time has fully come for medical science to stand side by side with other sciences and to be represented with them in this association.

I was expected on this occasion not to make a formal address but simply to reply to the cordial words of welcome which have been extended to us on behalf of the university and of the city. The evil day, fortunately for you and for me, seems by the plan of organization to be put far off, when the incoming president is expected to make his formal address to the association.

I now have pleasure in declaring this fifty-sixth session of the American Association for the Advancement of Science open, and I trust that the sessions of the association and the meetings of the several sections and affiliated societies will be full of interest and profit to all in attendance.

After announcements by the general, permanent and local secretaries, the general session of the association was adjourned.

JAMES MILLS PEIRCE.

ONE summer morning nearly forty years ago the boys who were to take their examinations for admission to Harvard College were assembling in Harvard Hall to meet the officer in charge of the examinations, Professor James Mills Peirce. As the room filled he walked slowly up and down the platform, his hands clasped behind his back in a manner very familiar to all his friends, looking now at the boys, now out of a window, but saying not a word. One of the boys, now himself a professor in the university, leaning over, whispered in Greek to his friend an adapted line of Homer—"Behold him as he walks, the shortest of them all, but kingliest of men." Such was the impression made then and always by James Peirce on those who were fortunate enough to meet and know him. It is the purpose of the following sketch to give some account of his life together with a short description of the changes which, during his fifty years of service, took place in Harvard University.

James Mills Peirce was born in Cambridge on May 1, 1834. He was the son of Benjamin Peirce, the great mathematician, and Sarah Mills Peirce. The father of Benjamin Peirce, also named Benjamin, was librarian and the first historian of Harvard College. James Peirce's maternal grandfather was a representative in congress, later senator from Massachusetts, and a colleague of Daniel Webster. James Peirce graduated from Harvard College in 1853. The next year he spent at the Law School. In 1854 he gave up the study of law to become a tutor in mathematics in Harvard College. In 1857 he entered the Divinity School, retaining his position as

tutor, however, until 1858. After graduating in 1859 from the Divinity School, he spent the next two years preaching in the Unitarian churches in New Bedford, Mass., and in Charleston, S. C. In 1861 he gave up the ministry to return to Harvard as assistant professor of mathematics, and remained in the service of the university until his death. In 1869 he was made professor of mathematics, and in 1885 appointed to the Perkins professorship of mathematics and astronomy. He served as secretary of the Academic Council from its establishment in 1872 until 1889, as dean of the graduate school from its foundation in 1890 until 1895, and as dean of the faculty of arts and sciences from 1895 until 1898. His resignation from the faculty, to take effect in March, 1907, on the completion of fifty years' service as a teacher in the university, was accepted by the president and fellows only a few weeks before his death. He died suddenly of pneumonia on March 21, 1906, in the seventy-second year of his life and in the fiftieth year of his service as a teacher in the university. It is a curious coincidence that his father also died in the seventy-second year of his life and in the fiftieth of his service in the university.

The period from 1860 to 1880 was a time of great changes in the university, the development of the elective system, and the beginning of the graduate school. With these changes James Peirce had much to do. It may justly be said that the great work of his life was the development of graduate instruction in Harvard University. Accordingly I purpose to give some account of the condition of the mathematical instruction at Harvard at the beginning of his academic career, and to show by following its development the growth of the elective system, the beginning of graduate instruction, and to trace, as far as

possible, his influence in this period of transition.

In 1853 when he graduated from college the mathematical instruction was given by his father, Professor Benjamin Peirce, and by a single tutor, Mr. C. F. Choate. The course consisted of required freshman work in plane and solid geometry, algebra and plane trigonometry; of required sophomore work in algebra, spherical trigonometry and analytic geometry; of elective courses for juniors and seniors in 'imaginary, integral and residual calculus,' in mechanics, and in astronomy. All college work in the freshman and sophomore years, and in the junior and senior years three fifths of the work, was required. The elective system, though undeveloped, had already had its beginning. About 1849 this small privilege of election was in danger of being withdrawn by the faculty; at one time a majority of this body actually favored making the whole course required. The elective system was saved at that time by the determined fight of a few liberal-minded men, prominent among whom was Benjamin Peirce.

In 1854 Tutor Choate resigned and in his place James Peirce was appointed. In the same year his classmate, Charles W. Eliot, was also appointed tutor in mathematics, the teaching force of the department being thus increased to three. The tutors hereafter carried on the freshman and sophomore work, leaving Professor Benjamin Peirce free for more advanced work. James Peirce, having the first appointment, had the choice between freshman and sophomore work. With a modesty which always characterized him, he decided to teach the freshmen, believing himself not so well qualified to give the sophomore instruction as to teach the more elementary freshman subjects.

At this time examinations in all college

courses were conducted orally by the instructors acting with examining committees appointed by the overseers. These examinations, far from being severe, were in some cases almost farcical. Some professors held rehearsals of the examinations prior to the visits of the overseers' committees; others gave the examinations in such a manner that a student might without difficulty discover just what question would be asked him, and prepare himself accordingly. Furthermore, the time for examining a student on one subject could not be extended beyond two or three minutes. It may be imagined that the passing of examinations was not a difficult matter. Indeed, it was not necessary for a student to pass even these examinations. For the faculty could not be prevailed upon to refuse its degree to a student, however bad his scholarship, if his conduct during his residence at the university had not incurred serious censure. It happened once in the early fifties that the faculty was almost persuaded not to vote a degree to a student of greater than usual incapacity, when it was discovered that the candidate had not once during his four years absented himself from prayers. The degree was granted without further debate.

Tutors Peirce and Eliot, dissatisfied with these oral examinations, introduced, during their first year, occasional written hour examinations in place of the regular recitations. These examinations were used by the instructors in making their reports, but did not replace the annual oral examination held in the presence of the overseer's committees. Other instructors, notably the teachers of the classics, followed the lead of the mathematical department. This new system of examination, requiring real knowledge, on the part of the student, proved disastrous to the lazy and incompetent, and though bad reports of a stu-

dent's scholarship did not at first prevent his obtaining a degree, the results soon made evident the impracticability of requiring every man to do the same work. There was resistance on the part of both faculty and overseers to the introduction of written examinations, and a still greater resistance to the abandonment of a system of required studies. But before very long even the most conservative members of the faculty were forced to admit that the real examination must be a written one. At a conference held by committees of the faculty and overseers were passed five resolutions concerning examinations, which were unanimously adopted by the faculty on March 9, 1857. Of these resolutions the most important were the following:

1. Examinations in all courses shall be annual and in writing.
2. All marking shall be done by the instructors.
3. All examinations shall be prepared and printed by the instructors, and shall be submitted to the several (overseers') committees previous to the examinations.

The introduction of written examinations was largely due to James Peirce and Charles W. Eliot. It made apparent the necessity of giving students a greater field of choice in their studies, but it did not by any means bring with it the modern elective system. For the next ten years, almost to the time when Mr. Eliot became president of the university, there was in the faculty a struggle between the advocates and the opponents of the elective system. The faculty at that time consisted of about fifteen members. The younger members and one or two of the elder ones were in favor of giving the college the elective system. But not till 1868 was any change made in the required mathematics for freshman and sophomores. For the first time in the academic year 1868-69 sopho-

mores were not required to study mathematics. Under the administration of President Eliot the elective system developed rapidly, but no further change in the mathematical requirement appears until 1884, when the freshman requirement was dropped. From the autumn of that year the study of mathematics in Harvard College has been wholly elective. Just what part James Peirce played in the development of the elective system is uncertain. He was active always for the freeing of students from restrictions, and for any movement which seemed to him likely to promote true scholarship. He was an advocate of the elective system, and was always, in the faculty, a staunch supporter of every step in the direction of greater liberty to the student.

He was absent from Cambridge from 1859 to 1861. In 1861 he returned to the university as assistant professor of mathematics. In the previous year Mr. Eliot had been made assistant professor of mathematics, but in this year he was called to take charge of the work of the scientific school. The mathematical teachers in Harvard College were then Professor Benjamin Peirce, James Peirce and a single tutor, Solomon Lincoln. In the courses of instruction offered in that year the only change from the list of 1853 is the addition of an elective in quaternions, given by the elder Peirce.

In 1863, at the request of a number of professors, the corporation ordered that—

The president, with the (full) professors in all departments of the university, be authorized to meet and associate themselves in one body for the consideration of its educational interests, and for the arrangement of such courses of lectures as may be thought expedient for the benefit of the members of the professional schools, graduates of this or other colleges, teachers of the public schools of the commonwealth, and other persons.

This body was known as the university senate. The establishment of the senate

laid the foundation of the graduate school, in the development of which James Peirce, though not a member of the senate, played a prominent part. This body instituted various courses of 'university lectures,' including, in the words of James Peirce, 'many of high value and interest in all departments of learning.' These courses were generally short, consisting each of not more than five or six lectures. In 1863-4, the first year of the lectures, three courses were given on mathematical subjects: 'The Theory of Space developed by Quaternions' and 'The Connection of the Physical and Mathematical Sciences,' by Benjamin Peirce, and 'Special Investigations in Dynamics,' by William Watson. In the following year these courses were repeated with the addition of a fourth on 'Determinants' by James Oliver. Apparently the courses in mathematics did not meet with a very cordial reception, for in the third year only one mathematical course was offered, 'The Development of the Universe,' by Benjamin Peirce. Indeed, it may be supposed that this course was philosophical as much as mathematical. In 1866-7 this course was repeated, and Thomas Hill, the president of the university, gave courses on 'Methods of Teaching Elementary Mathematics,' and on 'A Constant Product.' In 1867-8 Benjamin Peirce gave for the first time a course of university lectures on 'Linear Calculus.' It is probable that this course dealt with the linear associative algebras invented and developed by him. In that year James Oliver gave a course on 'Geometry of Three Dimensions.' In the following year there were no courses of university lectures in mathematics, but in the catalogue of the scientific school, which was at that time an institution especially intended for advanced study and research, is printed this note: 'Private instruction in the various branches

of mathematics will be given to those desirous of receiving it by competent instructors residing at the university.' These instructors were Professor Benjamin and James Peirce.

In the autumn of 1869 Charles W. Eliot became president of the university, and at once occupied himself with the development of the advanced instruction. Various short courses in related subjects were combined; many new and longer courses were offered. To quote again the words of James Peirce, 'a settled purpose was manifested to establish the instruction of advanced special students on a permanent and efficient footing.' In addition to certain university lectures there were offered that year two 'university courses of instruction,' one in philosophy and one in modern literature, each consisting of three lectures a week throughout the year, and each given by several instructors. The university lectures in mathematics were 'Linear Algebra,' thirty-five lectures by Benjamin Peirce; 'Algebraic, Periodic and Double Periodic Functions,' thirty-five lectures, and 'Higher Geometry,' eighteen lectures by James Peirce. This was the first year in which James Peirce gave university lectures. It was, too, the first time that any branch of the theory of functions was taught at Harvard. In this year the regular elective courses in mathematics were greatly increased in number, and James Peirce was then and thereafter entirely freed from giving freshman instruction. He taught that year four elective courses, each of two hours a week, on analytic geometry, differential calculus, integral calculus and elementary mechanics. Four electives were offered also by his father, consisting each of from one to three lectures a week, on mechanics, astronomy, quaternions and linear algebra.

During the next ten years there were no

important changes made in the regular courses offered in mathematics. Benjamin Peirce, who was in 1869 sixty years of age, withdrew somewhat from active academic work, giving after 1870 not more than two courses a year, those generally on 'Quaternions, Mechanics and Linear Algebras.' The teaching of the elective courses was taken over almost wholly by James Peirce. He gave a great variety of courses, usually giving about twelve lectures a week. In 1870-1 he gave for the first time a regular course on 'The Theory of Functions,' in 1874-5 a course on 'Elliptic Functions,' in 1876-7 a course on the 'Functions of a Complex Variable,' following Briot and Bouquet. In 1878-9 he gave for the first time an elementary course on quaternions, his father giving the second course. In the following year James Peirce gave the advanced course, his father giving the first course. This plan of giving courses of two years on one subject, with two instructors alternating, has since that time been often followed at Harvard.

In 1870-1 the mathematical university lectures consisted of two courses, one on 'Celestial Mechanics,' two lectures a week for half the year by Benjamin Peirce, and a course of the same length on 'Modern Methods in Geometry' by James Peirce. The latter course has now become a fixture in the elective courses given every year, and, under the name of mathematics 3, is known to almost all students of mathematics who have been at Harvard during the last thirty years. In this year the number of courses of university lectures offered was thirty-three. The number of persons recorded in the catalogue as attending them is twenty-six.

Whether or not on account of the small attendance, it was found that the university lecture system was not satisfactory, and in 1872 these lectures were abandoned.

The university senate was reorganized as the academic council. The new body consisted of all professors, assistant professors and adjunct professors in all departments of the university. The degrees of Ph.D. and S.D. were instituted. The principal functions of the academic council were the administration of these degrees and the degree of A.M., and the superintendence of the advanced instruction. James Peirce was elected secretary of the council at the first meeting and continued to hold this position until 1889, when the chief functions of the body were transferred to the administrative board of the graduate school. In this capacity he practically had charge of the graduate instruction. He was behind every movement for giving the student greater privileges, as he was in favor of every change calculated to improve the quality or to raise the standard of instruction. In 1873-4 there were at the university forty candidates for the higher degrees. In 1894-5, the last year of his official connection with the graduate school, there were 255 resident graduate students, and 17 non-resident graduate students. The courses intended for advanced students were after 1872 regular elective courses and appear in the catalogue with the other electives. In the catalogue for 1875-6 appears for the first time a separate list of courses, twenty-five in number, intended especially for graduate students. In 1894-5 there were given 77½ courses intended primarily for graduates, 101½ intended for graduates and undergraduates. The development of the graduate instruction from 1872 to 1895 was steady but marked by no striking change. Of interest in this connection are the closing words of the last report made to the president of the university by James Peirce as dean of the graduate school. He writes in 1895:

I account it a high privilege that I have held the position of executive officer of our graduate department since it was first established in January, 1872. I have seen it struggle for years against the coldness and scepticism of many members of our own faculty and against untoward conditions in its constitution and in outward circumstances; and I now have the happiness of beholding it the acknowledged representative of the best culture, the most advanced science and the highest liberal learning of the university. I am fully conscious that I can claim nothing for myself in this progress, beyond a faithful service and an earnest endeavor to rivet attention to the highest ideals of intellectual work as furnishing the only true basis of the development of such a school. The graduate school is a genuine outgrowth of the demands of a generation of students now coming forward in America; and it is destined within a few years, as I confidently believe, to an expansion which will make its present prosperity look small. To this university it is already rapidly becoming the much needed regenerator of the motives and principles of student life; the open door which is admitting to us a national constituency; the western window letting in a flood of warmth and light to dissolve academic selfishness and narrowness, and to quicken us in the discharge of our highest duty, that of devotion to the service of our country and our time. When its own relations to the college proper have been satisfactorily established, through a wise readjustment of the grounds of our several degrees, it will gather into one bright focus the influence and authority of the scholarship of this university, and will carry on the name of Harvard to be still a conspicuous symbol of light and power to the coming century, as it has been to that which is nearing its close.

From the time of his father's death, in 1880, James Peirce was at the head of the mathematical instruction of the university. At the beginning of his service the teaching force was composed of one professor and two tutors; at the time of his death there were in the department of mathematics five professors, one assistant professor and two instructors. In 1854 the instruction offered embraced the required elementary freshman and sophomore work, and three elective courses. In 1905-6

there were offered five and a half courses primarily for undergraduates, of which two are of as advanced a nature as the electives offered in 1854; six courses intended for graduates and undergraduates; seven and a half courses of lectures primarily for graduates, and six courses of reading and research; in addition many other courses are named and described in the catalogue which are to be given in following years. As chairman of his department James Peirce was a most liberal-minded and conscientious administrator. He favored always the introduction of new courses, he was always desirous that the younger teachers should have an opportunity to give advanced instruction, he was scrupulously careful and painstaking in the details of administrative work. He seldom tried to impress his own opinion on the department, but preferred to be guided by the wish of the majority.

He gave himself a great variety of courses. Although his chief interest lay along the lines followed by his father, quaternions and other linear associative algebras, he was also much interested in geometry and in mechanics. In 1904-5 he returned to the teaching of mechanics after having laid the subject aside for many years. The course in which he is best known to the present generation of students are the two courses on 'Quaternions,' mathematics 6 and 9, and courses on 'Algebraic Curves and Surfaces,' mathematics 7a, 7b and 7c. These courses were well attended, especially those on 'Quaternions,' the number of students in mathematics 6 ranging from ten to twenty-five. He gave usually a course or two half courses each year, to a small number of students, on 'Linear Associative Algebras' or on the 'Algebra of Logic.' He never fell into the narrowing habit of giving year after year the same courses, but was eager always to

undertake the teaching of some new branch of mathematics. In the last year of his life he gave a new half-course, an 'Introduction to Higher Plane Curves,' to serve as a preparation for his other courses on that topic. Indeed, so anxious was he to avoid falling into a rut that he made very slight notes for his lectures, preferring, in repeating a course, to work it out anew. This method resulted in a continual freshness and variety of presentation in his teaching. His courses were conducted by lectures, but his students had always opportunity for questions and discussion. His lectures were extremely clear and excellent in form. He loved to develop a subject with great generality without, however, sacrificing detail. In his courses he covered the ground slowly, and a younger generation of students have occasionally felt some impatience with his very careful and methodical discussions. He was not a great believer in the 'problem method' of teaching and he gave almost no home-work to his students. He was a mathematician of wide and varied learning. His life was given to his teaching, and to administrative work, rather than to research. He published little. In 1857, at the age of twenty-three, he published an 'Analytic Geometry,' based on a part of his father's famous work called 'Curves and Functions.' This 'Analytic Geometry' was used for many years as a text-book at Harvard, and was considered an admirable treatise. Of it Joseph Henry Allen, writing in the Harvard Register in 1881, says: 'I call '(it) the very best text-book I ever used, and I never cease to bewail (that it) has gone out of print if not out of use.' This book, of 228 pages, contains a development of the elements of the subject with the usual applications to the study of conic sections. Written in a very attractive style, it is much more interesting reading, though it

would, perhaps, not be so useful in the class-room, than the modern text-book. It contains some explanation of the applications of conic sections to physical problems, and some sections which are in the author's own words 'speculative.' In 1873 he published a book of 83 pages on 'The Elements of Logarithms'; in 1888 a pamphlet of 67 pages called 'An Outline of the Elements of Analytic Geometry.' This is something more than a syllabus; it is rather a summary of the principles of the subject with short explanations. He published several books of mathematical tables, of which the last, 'Mathematical Tables Chiefly to Four Figures,' was published in 1879. These tables are well arranged and are widely used. He wrote few articles for scientific periodicals, the last one being 'On Certain Systems of Quaternion Expressions and on the Removal of Metric Limitations from the Calculus of Quaternions,' printed in the *Transactions of the American Mathematical Society* for October, 1904. He was the author of a few other short articles, one of which is 'A Rule Relating to the Calendar,' which appeared in the *Harvard Register* in 1881. He edited in 1881 a course of Lowell lectures given in 1877-8 by his father, to which he added certain appendices. In the course of his administrative work he wrote, as dean of the graduate school and as dean of the faculty, numerous reports to the president of the university, remarkable for their clearness and even more so for the richness and dignity of his style.

Professor Peirce was interested always in the social side of mathematics. When he began to teach at Harvard there was a mathematical club which held weekly meetings during the term in the lecture room of Professor Benjamin Peirce in University Hall. The club was small and not confined to members of the university. At

the meetings James Peirce sometimes spoke. In later years a 'Mathematical Conference,' established by the department, has held fortnightly or monthly meetings, at which papers were presented by the students and, less often, by members of the teaching force. James Peirce was usually present at these meetings, attending them probably oftener than any other member of the faculty. Once or twice he presented papers, among the last, one of great interest on the history of mathematical teaching in Harvard University. Two years ago these conferences were discontinued, and were replaced by a mathematical club to which belonged both the teachers and the students of mathematics. In this club, too, Professor Peirce took the greatest interest, and at its first meeting read a paper on 'The Analytic Geometry of Descartes.'

In 1881 was founded by the teachers of mathematics and physics of Harvard and of the Massachusetts Institute of Technology a club known as the M. P. Club, the purpose of which was to bring together the teachers and advanced students of these subjects at both institutions as well as other people interested, to hear and discuss short papers, and to provide pleasant social intercourse. James Peirce was elected its president, and continued to serve in this office until his death. He gave the club much thought and time, and took a deep interest in its welfare. One meeting each year was usually held at his house and that meeting was generally the pleasantest of the year. Of late years he felt that he had served too long as the club's president, and on several occasions offered his resignation, but in his own phrase, he always returned to his home 'unresigned.' He was a very regular attendant and a most modest and charming presiding officer. The first subject discussed by this club was 'Can there be a discontinuous

function?' It was voted after debate that no discontinuous function exists.

At the time of his last illness plans had already been made for an anniversary dinner of the club, at which a loving cup was to have been presented to him as a token of the appreciation, felt by the members, of his quarter century of service as president.

No man could have been more closely identified with Harvard University than was James Mills Peirce. Born and educated in Cambridge, he spent there nearly every winter of his life. From the time of his entrance into Harvard College as a freshman in 1849 until the death of his father in 1880 he lived in the college yard as student, tutor and professor.

He was a man of most sweet and friendly disposition, kind to all with whom he came in contact, slow to anger, aroused only by injustice; a man of wide acquaintance and of many friends, most hospitable in his own home, fond of society and given to sociability. A lover of music and widely read in English literature, he was a man of the broadest intellectual interests.

What marked him most was a great faithfulness. He never faltered in his work, he never lost interest, indeed his enthusiasm grew greater from year to year. The welfare and the usefulness of the university were his dearest concern, and for their advancement was given the whole of a long and active life. He died, as we must suppose he would have chosen to die, working to the end.

J. K. WHITTEMORE.

HARVARD UNIVERSITY.

DISCUSSION AND CORRESPONDENCE.

NORTHERN LIMIT OF THE PAPAW TREE.

SOME years ago I was surprised to receive from a correspondent, Mr. Kennyon, of McGregor, Ia., a specimen of the papaw tree found native in the vicinity of McGregor.

Below McGregor on the Mississippi, between Dubuque and Specht's Ferry, quite a number of specimens of this plant were observed. Some years later, while botanizing in the vicinity of Clinton, Ia., the species was found in flower. I have never seen any fruit at any point near here, but feel warranted in saying that the plants are perfectly hardy and do bear fruit. In all of these cases the plants were found growing on the sides of limestone hills. It may be of interest also to note in this connection that the pecan also occurs on the Mississippi at Savannah, Ill., which is somewhat north of the latitude usually given for it. While it is true that the Indian may have been an agent in the dissemination of the seed of the papaw, it was probably also disseminated in other ways.

L. H. FAMMEL.

THE CRAYFISH INDUSTRY.

IN my recent article on 'The Future of the Crayfish Industry,' in SCIENCE, June 29, two errors appear on page 984. The value \$420 in line fourteen should be \$4,200 and the amount of 165,000 in line twenty-two should be 116,400, as *correctly* stated in the statistics of the Bureau of Fisheries.

E. A. ANDREWS.

SPECIAL ARTICLES.

EMISSION OF ELECTRICITY FROM THE RADIUM PRODUCTS.¹

HITHERTO, the rate of decay of the induced activity produced by radium, has not been studied by means of the charge carried away from the active body by the α and β rays.

The following is a brief report of the results of two series of experiments on the charge of electricity carried by these rays.

In the first series of experiments, a metal wire was made active by immersion in radium emanation; and immediately after removal from the emanation vessel, was placed inside a small hard rubber tube, with very thin walls. The outside of the tube was surrounded by

¹ An abstract of a paper read before a meeting of scientists, at the University of Colorado, on May 5, 1906.